Unconformit

Kcl

Jīkos

Unconformity(?)

Maw Mawc

Dkln

Holocene

Upper

Lower

Lower

Upper

Devonian

Mississippiai

Cretaceous

Cretaceous

QUATERNARY

CRETACEOUS

JURASSIC

TRIASSIC

PERMIAN

MISSISSIPPIAN

DEVONIAN

MAP A. GENERALIZED GEOLOGY AND LOCALITIES OF SEDIMENT SAMPLES

Table 1. Methods of analysis of minus-100-mesh stream- and lake-sediment samples collected from the northern part of the Chandler Lake quadrangle [All values in parts per million unless otherwise noted; INAA instrumental neutron activation analysis: XRF, energy

dispersive X-ray fluorescence; DNC, delayed neutron counting]

Element	Analytical Method	Lower detection limit
Al	INAA	0.52%
Ag	XRF	7
As	XRF	5
Au	INAA	0.06
Ba	INAA	160
Bi	XRF	5
Са	INAA	0.10%
Cd	XRF	5
Се	INAA	17
Co	INAA	2
Cr	INAA	19
Cs	INAA	1.6
Cu	XRF	10
Dy	INAA	1
Fe	INAA	0.17%
Hf	INAA	1.5
K	INAA	0.49%
La	INAA	10
Lu	INAA	0.2
Mg	INAA	0.14%
Mn	INAA	23
Na	INAA	.02%
Ni	XRF	15
Pb	XRF	5
Sn	XRF	10
Sc	INAA	1.0
Th	INAA	1.6
Ti	INAA	0.1%
U	DNC	0.16
V	INAA	12
W	XRF	15
Yb	INAA	1.7
Zn	INAA	40
Zr	XRF	20

* For elements analyzed by INAA, lower detection limit varies as a function of

the composition of sample; value listed is the lowest reported value of the

detection limit for each element

GEOCHEMISTRY OF SEDIMENT SAMPLES FROM THE NORTHERN PART OF THE CHANDLER LAKE QUADRANGLE, ALASKA

Any use of trade names in this publication is for descriptive purposes only and does not imply endorsement by the U.S. Geological Survey INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—199 For sale by U.S. Geological Survey Map Distribution

EXPLANATION Major folds---Showing direction of plunge where known Overturned anticline Syncline--- Dashed where inferred position of strata that formed syncline is found in upper thrust plate and since been eroded Strongly asymmetrical syncline---Double dip arrow indicates steeper dipping limb Overturned syncline Thrust fault---Sawteeth on upper plate Detachment surface---Approximately located. Sawteeth on upper plate Fault---Type uncertain; ticks indicate hanging-wall block Shear zone---Melange; zone of pervasively sheared and structurally Outcrops of radiolarian ribbon chert and very cherty rhytmically bedded limestone Outcrop of basalt---Locally pillowed

Tectonic block of coquinoid limestone in melange

Outcrops of shaly strata in undivided part (Dh) of Hunt Fork Shale

Well---Drilled for oil and gas; abandoned

Minus-100-mesh sediment sample locality

Minus-80-mesh stream-sediment sample locality

STUDIES RELATED TO AMRAP The U.S. Geological Survey is required by the Alaskan National Interest Lands Conservation Act (ANILCA, Public Law 96-487, 1980) to survey Federal Lands to determine their mineral resource potential. Results from the Alaskan Mineral Resource Assessment Program (AMRAP) must be made available to the public and be submitted to the President and the Congress. This report presents an interpretation of geochemical data collected from the northern part of the Chandler Lake quadrangle as part of the National Uranium Resource Evaluation (NURE) program.

INTRODUCTION

The Chandler Lake quadrangle is located in the central part of the Brooks Range and Arctic Foothills provinces of northern Alaska (fig. 1). A geochemical investigation of the Chandler Lake quadrangle has been underway since 1981 as part of the Alaskan Mineral Resource Assessment Program. The purpose of the survey was to define geochemical variations within the quadrangle and locate areas favorable for mineralization. Unconsolidated stream sediments, nonmagnetic heavy-mineral concentrates derived from the stream sediments, and rock samples were used for the study. This report presents an interpretation of stream- and lake-sediment data collected from the northern part of the Chandler Lake quadrangle as part of the NURE program (Los Alamos National Laboratory, 1982). It is one of a series of three reports that graphically present selected geochemical and mineralogical data in map format. Other reports in the series include an interpretation of geochemical and mineralogical data from nonmagnetic heavymineral-concentrate samples and stream-sediment samples collected from the southern part of the Chandler Lake quadrangle (Kelley and others, 1993a; 1993b). A comprehensive report on the mineral resource assessment of the quadrangle is also currently underway (S.E. Church and others, written communication, 1992).

GENERALIZED GEOLOGY The southern boundary of the Chandler Lake quadrangle, which lies south of the Brooks Range continental divide, is within the Brooks Range Province of Wahrhaftig (1965) (fig. 1). The northern and southern foothills areas of the Arctic Foothills Province comprise the northern two-thirds of the

Map A shows the generalized geology of the Chandler Lake members: the wacke member consists of gray-green wacke interbedded with shale, siltstone, and sandstone, and the shale member consists of dark-gray and olive shale interbedded with brown-weathering calcareous siltstone and fine-grained sandstone. Both members represent deposition in a marine

Noatak Sandstone, which in turn is overlain by a nonmarine sequence belonging to the Upper Devonian and Lower Mississippian(?) Kanayut Conglomerate (Nilsen and Moore, 1984). The Kanayut Conglomerate is as thick as 2,600 m and extends across the Brooks Range for more than 800 km from east to west (Nilsen and Moore, 1984). The Kanayut Conglomerate contains a coarse middle part of interbedded conglomerate and sandstone, and upper and lower parts consisting of sandstone, siltstone, and shale. The conglomerate contains clasts of chert, quartz, quartzite, and argillite (Brosgé

and others, 1979; Nilsen and others, 1981). Sedimentary features in the Kanayut Conglomerate indicate that deposition occurred in a deltaic environment with chert-rich source areas to the north and northeast (Nilsen

The Hunt Fork Shale-Kanayut Conglomerate sequence represents a southward- or southwestward-prograding deltaic complex; the coarse deltaplain deposits of the Kanayut grade downward into the marine sandstone of the Noatak Sandstone, the wacke member of the Hunt Fork Shale, and the prodelta shales of the lower part of the Hunt Fork Shale (Nilsen and Moore, 1984). The Kanayut Conglomerate, therefore, forms the fluvial part of the delta that prograded to the southwest during the Late Devonian and retreated during the Late Devonian and Early Mississippian(?) (Nilsen and others,

Overlying the Kanayut Conglomerate are fossiliferous marine strata of the Lower Mississippian Kayak Shale that consist of shale, siltstone, and shaly sandstone interbedded with argillaceous and ferruginous limestone (Brosgé and others, 1979). The Mississippian Lisburne Group (Patton and Tailleur, 1964) overlies the Kayak Shale and consists primarily of medium- to light-gray limestone and dolomite with dark-gray phosphatic limestone, shaly limestone, chert, and shale.

The Permian Siksikpuk Formation disconformably overlies Lisburne Group carbonate rocks. The Siksikpuk Formation has been subdivided into four lithostratigraphic subunits (Siok, 1985); the subunits consist of a lower gray to greenish-gray pyritic siltstone, greenish-gray to maroon mottled mudstone and siltstone, greenish-gray silicified mudstone or chert, and an upper gray shaly horizon. The lowermost units weather orange and yellow because of alteration of pyrite to jarosite (Siok, 1985). The greenish-gray to maroon siltstone and mudstone locally contain barite lenses and nodules. The lithostratigraphic sequence of the Siksikpuk Formation is consistent throughout the Killik River quadrangle to the west and throughout the western part of the Chandler Lake quadrangle (C. G. Mull, written commun., 1987). However, in the eastern part of the Chandler Lake quadrangle, the unit consists mostly of shale and lacks a consistent chert

Overlying the Siksikpuk Formation is the Lower Triassic to Middle Jurassic Otuk Formation, which consists of dark-gray and greenish-gray marine shale, dark-gray to black chert, and impure limestone interbedded with dark-gray and black shale (Mull and others, 1982). The chert beds typically weather brown or green. As with the Siksikpuk Formation, the Otuk Formation becomes less cherty in the eastern part of the quadrangle; the unit here is more characteristic of the Triassic Shublik Formation, which consists of primarily shale and impure limestone (Patton and Tailleur, 1964). The Otuk is distinguished from the underlying Siksikpuk Formation by the color and weathering characteristics of the chert and shale (Mull and others, 1982). The Hunt Fork Shale, Noatak Sandstone, Kanayut Conglomerate, Kayak Shale, Lisburne Group, and Siksikpuk and Otuk Formations, which form the mountains and the mountain front, comprise the Endicott Mountains allochthon, the structurally lowest allochthon in the central Brooks Range

North of the Endicott Mountains front is the southern foothills belt, which consists of primarily Mississippian to Lower Cretaceous rocks referred to by Kelley (1990) as the Arctic Foothills assemblage (map A). The assemblage consists of Lower Cretaceous coquinoid Permian and Triassic chert, rocks of the Nuka Formation (Mississippian and Pennsylvanian?), marble, and melange.

Most of the Arctic Foothills assemblage probably is structurally repeated, complexly deformed, and tectonically disrupted (Kelley, 1990). The complexly deformed rocks are overlain by gently folded shale, graywacke, and conglomerate of the Lower Cretaceous Fortress Mountain Formation (restricted). The west-central part of the quadrangle is underlain by a thick sequence of nonresistant and tightly folded marine shale, mudstone, siltstone, and thin-bedded sandstone of the Lower Cretaceous Torok Formation (Detterman and others, 1963).

The northern foothills area contains gently deformed sedimentary rocks of the Nanushuk Group (Detterman and others, 1963; Huffman, 1989), which consists of the Lower Cretaceous Tuktu and Grandstand Formations the Lower and Upper Cretaceous Chandler Formation, and the Upper Cretaceous Ninuluk Formation. These sedimentary rocks represent a deltaic complex composed of interbedded conglomerate, sandstone, coal, and shale, which were derived from the Brooks Range and prograded northward and eastward into the Colville trough (Mull, 1982). This clastic wedge is folded into a series of long, linear, east-west-trending anticlines and synclines. Overlying the Nanushuk Group in the northern Chandler Lake

quadrangle are relatively small exposures of Upper Cretaceous sedimentary rocks preserved in the axes of regional synclines. These rocks consist of marine shale, siltstone, sandstone, bentonite, and tuff of the Upper Cretaceous Seabee and Schrader Bluff Formations separated by the thin nonmarine sandstone and conglomerate of the Prince Creek Formation (Detterman and

Map A shows the localities of sediment samples collected in the northern part of the Chandler Lake quadrangle. A total of 613 stream- and lake-sediment samples were collected and analyzed by Los Alamos National Laboratory (1982). Where possible, sediment samples were collected in small active stream channels; lake sediments were collected in areas with poorly developed drainages. Sediment samples were collected at a density of approximately one sample per 10 km². For stream sample sites, approximately 1 kg of organic-rich, clay-sized material was composited from three spots in the active stream. For lake sample sites, a tethered stainless steel bottom sampler was dropped near the center of the lake from a pontoon-equipped helicopter. The samples were dried at about 100° C prior to sieving to minus-100 mesh (Bolivar, 1980).

The minus-100-mesh sediment samples were analyzed at the Los Alamos National Laboratory using delayed-neutron counting (DNC), instrumental neutron-activation analysis (INAA), and x-ray fluorescence (XRF) (table 1). Due to elemental interference, the lower detection limits for elements determined by INAA will vary between samples as a function of the composition of the sediment (Bolivar, 1980). The lowest value of the detection limit for each element is shown in table 1.

Sixty minus-80-mesh stream-sediment samples and nonmagnetic heavy-mineral concentrate samples derived from stream sediments were collected from the northern part of the quadrangle by the U.S. Geological Survey in the summer of 1985. Geochemical and mineralogical data obtained from these samples were used in the interpretation of the NURE data. The samples were analyzed for 31 elements using a direct-current arc emission spectrographic method (Grimes and Marranzino, 1968). Gold in streamsediment samples was determined using an atomic absorption method (Thompson and others, 1968). The mineralogy of each nonmagnetic heavy-mineral-concentrate sample was determined by visual inspection using a binocular microscope. Details of sample collection, preparation, and analysis of minus-80-mesh stream sediment samples and nonmagnetic heavy-mineral concentrates are described in Sutley and others (1984).

Although stream- and lake-sediment samples may be considered two distinctly different sample media, data for the two media were combined prior to multi-element data analysis; initial evaluation of the two sample media as separate data populations revealed that most of the elements in each had similar concentration ranges, geometric means, and interelement correlation. The combined minus-100-mesh stream- and lake-sediment samples are

STATISTICAL SUMMARY

referred to throughout the text as "minus-100-mesh sediment samples". Table 2 is a statistical summary of the combined stream- and lake-sediment data. Qualified values are those that are less than the lower limit of detection (L). The detection ratio (DR) is the number of samples with unqualified values (determinant values) divided by the total number of samples analyzed. For instance, a detection ratio of 1.0 indicates that all samples yielded unqualified values for a particular element. Conversely, a detection ratio of 0.10 indicates that only 10 percent of the samples yielded unqualified values of a given element. Prior to calculation of the arithmetic mean and standard deviation, values qualified with "L" were set equal to one half of the lowest unqualified value. Only elements with a detection ratio of 0.3 or higher were used in the calculations. Elements that were highly censored (i.e., greater than 95 percent of the samples contain qualified values for a given element) are not included in table 2; these elements are Ag, Bi, Cd, and Sn.

elements. Geochemical anomalies were interpreted from the study of the histograms. If the distribution is approximately normal, the high background-possible anomaly boundary is commonly defined as the mean plus two standard deviations (Rose and others, 1979). If the distribution is bimodal or unclear, arbitrary boundaries are selected based on geologic and geochemical criteria. In general, we used a combination of the above criteria in determining the boundaries between background and anomaly.

Histograms were constructed for some of the relatively uncensored

FACTOR ANALYSIS AND INTERPRETATION OF GEOCHEMICAL DATA To aid in the interpretation of the regional geochemical data, we used R-mode factor analysis with varimax rotation to define the dominant geochemical associations. This type of factor analysis groups the elements that tend to behave similarly into multielement associations, or factors (Davis, 1973, p. 500). Factor loadings represent the contribution of each element onto each factor. Factor scores measure the "effect" of a factor on each individual sample. By grouping the elements into factors, a large number of variables are reduced to only a few variables that best characterize the original data. The factors produced from R-mode factor analysis reflect geological and geochemical processes.

Twenty elements were used in the factor analysis. We selected a four-factor model (table 3) based on factor-variance diagrams. This four-factor model, which explains 74 percent of the variance in the original data set, gives the most meaningful geologic solution for the reconnaissance

The distribution of samples with high scores for the four factors is shown on maps B and C. Factors 1, 3, and 4 (table 3) account for about 63 percent of the total data variability and represent lithogeochemical associations. Elements that load strongly onto factor 1 are Ba, Cs, Cu, K, Mg, Ni, Pb, Sc, Th, Ti, U, and V. Most samples with high scores for this factor

are spatially associated with exposures of sedimentary rocks of the Prince Creek and Seabee Formations in the northwest corner of the quadrangle, and with rocks of the Torok Formation in the central and western parts of the juadrangle (map B). Samples with high factor 1 scores are interpreted to have been eroded from shale within these formations. Throughout this report,

factor 1 will be referred to as the "shale factor". Drainage basins characterized by samples with high factor 3 scores (Cr, Hf, K, Th, Ti, U, V, and Zr) consist almost entirely of nonmarine sandstone of the Lower and Upper Cretaceous Chandler Formation. The trace-element signature of this factor probably represents the heavy minerals zircon (Zr, Hf, Th, and U) and rutile (Ti, and Cr) that may be present in the sandstone. We refer to this factor as the "sandstone factor" throughout this

Factor 4, with high loadings for Ba, Ca, and Mg, defines samples containing abundant limestone and dolomite fragments and (or) barite. Although the areas containing samples with high scores for this factor consist predominantly of rocks of the Arctic Foothills assemblage (an assemblage with a wide variety of rock types), the samples are most likely derived from the Lisburne Group limestone and dolomite, and the Siksikpuk Formation that crop out in the central part of the quadrangle. Barite lenses and nodules are common in the Siksikpuk Formation (Siok, 1985). Many nonmagnetic heavy-mineral-concentrate samples collected in the central part of the quadrangle contain more than 50 percent barite (Kelley and others, 1993b), and minus-80-mesh stream-sediment samples contain more than 2,000 ppm Ba (Kelley and others, 1993a).

Elements that load strongly onto factor 2 are As, Co, Fe, Mn, and Ni. Samples with high factor 2 scores are shown on map C. With the exception of a few samples that were collected along the northern border of the quadrangle, most samples with high factor 2 scores are located in the central part of the quadrangle, which consists primarily of rocks of the Arctic Foothills assemblage and the Torok Formation. This association of elements in the sediment samples probably indicates the presence of abundant concentrations of pyrite. Pyrite usually contains at least minor amounts of all of the elements listed above (Levinson, 1974, p. 68). In addition, some of the nonmagnetic heavy-mineral concentrate samples collected in the central part of the quadrangle contain ≥20 percent pyrite and trace amounts of arsenopyrite (map C). Thus, factor 2 probably represents pyrite in the sediment samples, and will therefore be referred to as the "pyrite factor". Given the spatial distribution of the localities of samples with high scores for this factor, the pyrite is most likely contained in Permian and Triassic shale units of the Arctic Foothills assemblage or shale of the Lower Cretaceous Torok Formation.

The localities of the 27 minus-100-mesh sediment samples that contain detectable concentrations of gold are plotted on map C. Gold concentrations in these samples range from 0.06 ppm to 1.73 ppm. They are located primarily in the northcentral and northeastern parts of the quadrangle map C). In order to verify the validity of these Au values, minus-80-mesh stream-sediment samples were collected in many of the areas containing Aubearing minus-100-mesh samples. It was not possible to sample the exact stream or location along a stream; however, streams in the vicinity of the Au-bearing minus-100-mesh sediments were sampled in most cases. There are 8 minus-80-mesh samples that contain detectable concentrations of Au; they range from 0.05 ppm to 2.4 ppm (map C). The corresponding nonmagnetic heavy-mineral-concentrate samples collected from the same localities as the minus-80-mesh stream-sediment samples did not contain visible Au or detectable concentrations of Au as determined by emission

Gold and tungsten

Concentrations of As in the Au-bearing samples are generally low (5-15 ppm in minus-100-mesh sediment samples; less than 10 ppm in minus-80-mesh stream-sediment samples), and only two of the minus-80-mesh samples that contain Au contain detectable Ag (0.5 ppm and 0.7 ppm). All other elements commonly associated with Au, such as Bi, Hg, and Sb, were either not analyzed or their concentrations were less than the lower limit of

The W concentrations in minus-100-mesh sediment samples are also plotted on map C; they range from 15 ppm to 38 ppm. None of the minus-80-mesh stream-sediment samples contain detectable W (the lower limit of determination is 50 ppm W for minus-80-mesh sediment samples). In the northern part of the quadrangle, most of the minus-100-mesh sediment samples containing detectable concentrations of W are located near the Aubearing samples; however, none of the W-bearing samples contain Au.

There is a cluster of samples with detectable W in the east-central part of the quadrangle. Many of these samples yielded high scores for the pyrite-factor (map C). In particular, samples collected from the May Creek and Cobblestone Creek basins (T.11S.; R.8E. and R.7E.) contain 15 ppm to 35 ppm W and have corresponding high pyrite factor scores. Nonmagnetic heavy-mineral-concentrate samples collected from these creeks do not contain detectable tungsten and no tungsten-bearing minerals (such as scheelite) were identified (Kelley and others, 1993b).

The source of the Au and W is difficult to determine. In the northernmost part of the quadrangle, most of the gold-bearing sediment samples were collected from streams that drain rocks of the Seabee, Prince Creek, and Schrader Bluff Formations. A few samples were collected in basins that drain nonmarine sandstone of the Chandler Formation. The W-bearing samples were collected in areas that contain rocks of the Chandler Formation. Farther south, detectable Au and W concentrations were found in samples collected from low, flat terrane with poorly defined drainage basins characterized by high-organic soils. Much of this area is covered by Quaternary surficial deposits, but some samples are from basins that clearly drain rocks of the Lower Cretaceous Torok Formation.

The anomalous concentrations of Au and W in the sieved fine-grained sediment samples, and the lack of anomalous concentrations of Au and W and the lack of native gold or W-bearing minerals in associated nonmagnetic heavy-mineral-concentrate samples suggests that either the Au and W are present in fine-grained minerals and are detected only in minus-80-mesh and minus-100-mesh sediment samples, or they are associated with relatively magnetic minerals (such as high-Fe pyrite and wolframite) and are not letected in nonmagnetic concentrates. The lack of qualified data for commonly associated elements (such as Ag, Bi, Sb, Sn, and Nb) in sediment samples and the absence of lithogeochemical data for rock units in these areas

makes any further interpretation impossible. Barium and zinc

Barium concentrations in minus-100-mesh sediment samples range from less than 160 ppm to 6,366 ppm (map D). The samples containing anomalously high concentrations (≥1,000 ppm) were collected in the central part of the quadrangle from tributaries of the Siksikpuk River, and in the eastcentral part of the quadrangle from May and Cobblestone Creeks; many of these samples also yielded high scores for the barite factor (map D). Many of the nonmagnetic heavy-mineral concentrate samples collected in these areas and immediately south contain more than 50 percent barite (grains are visible by microscopic examination) (Kelley and others, 1993b). There are several possible sources for the barite. Throughout the Brooks Range, barite is commonly present in the Permian Siksikpuk Formation (Mull and others, 1987), and in the Howard Pass quadrangle west of the Chandler Lake quadrangle it is also present as localized concentrations in carbonate rocks and chert of Mississippian age (J.S. Kelley, written commun., 1992). Within the Chandler Lake quadrangle, the only reported barite occurrences are nodules, veins, and clots of euhedral barite within the Siksikpuk Formation (Siok, 1985). The deposition of this barite probably occurred when barium-rich basinal fluids, possibly associated with oil generation in the underlying Lisburne Group, migrated up-section through the Siksikpuk Formation and precipitated barite in red siltstone when the barium-rich fluids encountered interstitial sea water and oxidizing conditions (Siok, 1985).

Although most of the minus-100-mesh sediment samples with high concentrations of Ba are distributed along the rangefront (which lies along the southern border of map D) there are also samples located about 16 km north of the rangefront (map D); the Siksikpuk Formation and the Lisburne Group carbonate rocks crop out along the rangefront only. Glacial transport of rocks northward from the mountain range (Hamilton, 1979) is probably the source of this train of anomalous Ba concentrations in the sediment samples. Concentrations of Zn in minus-100-mesh sediment samples range from <40 to 561 ppm. However, more than 50 percent of the values were qualified and, therefore, Zn was not included in the factor analysis. However,

it was plotted on map D to show the distribution of zinc in the minus-100-mesh sediment samples. Although the localities of samples with anomalously high zinc concentrations (200-561 ppm) are widely scattered throughout the northern

part of the quadrangle, most are located along Autumn Creek and the Siksikpuk River in the central part of the quadrangle, and in the eastern part of the quadrangle along May and Cobblestone Creeks. Some of these Zn-rich samples also contain high concentrations of barium (as discussed above), as well as high scores for the pyrite and barite factors (map D). These areas contain primarily rocks of the Lower Cretaceous Torok Formation, sedimentary and mafic volcanic rocks of the Arctic Foothills assemblage, and Quaternary alluvium, colluvium, and glacial deposits.

sediment samples range from 0.16 ppm to 5.69 ppm. The distribution of anomalous concentrations of U (3.0 to 5.69 ppm), and the U/Th ratios are shown on map E. Basin areas defined by samples with high scores for factors 1 (shale factor) and 2 (sandstone factor) are also shown. Many samples that contain anomalous U concentrations also yielded high scores for the shale factor; these were collected from basins draining the Prince Creek, Seabee, and Torok Formations. The high U contents in sediment samples collected in these basins is probably due to higher background concentrations of uranium in the black organic shales. Other samples with anomalous concentrations of U are coincident with high factor (sandstone factor) 3 scores. These samples were collected from basins consisting primarily of sandstone and siltstone of the Cretaceous Chandler Formation. Most of the sediment samples that contain anomalous concentrations of U have relatively low U/Th ratios (map E), indicating that Th is present in concentrations that are equal to or greater than those of U. Although some sandstone units

The U concentrations (determined by DNC) in minus-100-mesh

commonly host deposits of U-bearing minerals (that don't contain Th), the anomalous U concentrations.

relatively low U/Th ratios in sediment samples coincident with sandstone of the Chandler Formation suggests that minerals such as zircon, which incorporates both Th and U in it's structure, are responsible for the Many stream-sediment samples collected in the northeastern part of the quadrangle contain anomalous uranium concentrations and have relatively high U/Th ratios. These areas contain primarily rocks of the Seabee and

Chandler Formations and surficial deposits of Quaternary age. The high concentrations of uranium in samples collected in these areas may be associated with coal beds in these units; lignite and some other varieties of coal contain higher than average amounts of uranium (Boyle, 1974). The central part of the quadrangle is characterized by low, flat terrane with poorly defined drainage basins containing organic-rich soils and

sediments. The widely distributed anomalous concentrations of U and relatively high U/Th ratios in this area are most likely due to adsorption of uranium by the organic material. In conclusion, although there are several widely distributed samples with anomalous concentrations of U in the study area, most of the sediment samples contain low concentrations. Huffman (1985) measured the U contents of rocks of the Nanushuk Group in the northern Chandler Lake

Chromium and nickel

quadrangle and concluded that the potential for U resources in these rocks is

The distribution of minus-100-mesh sediment samples with anomalous concentrations of Cr (180-904 ppm) and Ni (55-110 ppm) is shown on map F. Their distribution is primarily in the northcentral and northwestern parts of the quadrangle. Nonmagnetic heavy-mineral-concentrate samples collected from these areas contain from 500 ppm to more than 10,000 ppm of both Cr and Ni. X-ray diffraction and laser microprobe analysis of selected grains identified the source of the anomalous Cr and Ni as one or more minerals of the spinel group. A chromium and nickel-bearing variety of spinel, with a unit cell (A = 8.36) close to magnesiochromite and (or) nickel-bearing magnetite Palache and others, 1944) was found in several samples.

Most of the sediment samples that contain anomalous concentration

of Cr and Ni were collected from basins consisting of rocks of the Lower and Upper Cretaceous Nanushuk Group, primarily the Chandler Formation, or of the Lower Cretaceous Torok Formation. Rocks of the Nanushuk Group represent a deltaic complex composed of interbedded conglomerate sandstone, coal, and shale. Sedimentary features in the conglomerate and sandstone units indicate the delta prograded northward and eastward from the Brooks Range. The magnesiochromite or nickel-bearing magnetite is most likely contained as a detrital mineral in sandstone and (or) conglomerate of the Chandler Formation of the Nanushuk Group or, alternatively, as a detrital mineral in Quaternary sands and gravels, having been reworked from the Cretaceous sedimentary rocks. The probable source was mafic and ultramafic igneous rocks to the south that were entirely eroded to produce the accumulation of chromite and thus anomalous Cr and Ni concentrations in sediment samples in the northern part of the Chandler Lake quadrangle. Several mafic and ultramafic igneous intrusions in the Howard Pass quadrangle west of the Chandler Lake quadrangle are host to podiform chromite bodies; chromite placers are also present in valleys that drain chromite-bearing ultramafic rocks (Foley and others, written commun., 1986). Highly anomalous concentrations of chromium (≥5,000 ppm) are present in ediment samples that were collected 50 km north of the intrusions in areas that do not contain exposed igneous rocks (Schmidt and others, written commun., 1991). Minor gold and palladium were detected in the most chromite-rich rock samples of the intrusions, but all sediment samples surrounding the intrusions and those located 50 km from the intrusions contain low concentrations of platinum-group elements and other precious

In the Chandler Lake quadrangle, gold concentrations in the Cr- and Ni-rich sediment samples are less than 0.05 ppm. The concentrations of platinum-group elements are not known, but they are probably similar to the ow concentrations found in sediment samples collected farther west of the Chandler Lake quadrangle in the Howard Pass quadrangle.

metals (Jeff Foley, written commun., 1991).

REFERENCES

Bolivar, S.L., 1980, The Los Alamos Scientific Laboratory approach to hydrogeochemical and stream sediment reconnaissance for uranium in the United States: Los Alamos Scientific Laboratory Report LA-Boyle, R.W., 1974, Elemental associations in mineral deposits and indicator

elements of interest in geochemical prospecting: Geological Survey of Canada Paper 74-45, 40 p. Brosgé, W.P., Reiser, H.N., Dutro, J.T., Jr., and Nilsen, T.H., 1979, Geologic map of Devonian rocks in parts of the Chandler Lake and Killik River quadrangles, Alaska: U.S. Geological Survey Open-File

Report 79-1224, scale 1:200,000. Davis, J.C., 1973, Statistics and data analysis in geology: New York, John Wiley and Sons, Inc., 550 p. Detterman, R.L., Bickel, R.S., and Gryc, George, 1963, Geology of the

Chandler River region, Alaska: U.S. Geological Survey Professional Paper 303-E, 323 p. Grimes, D.J., and Marranzino, A.P., 1968, Direct-current arc and alternating-current spark emission spectrographic field methods for the semiquantitative analysis of geologic materials: U.S. Geological

Survey Circular 591, 6 p. Hamilton, T.D., 1979, Surficial geologic map of the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field

Studies Map MF-1121, scale 1:250,000. Huffman, A.C., Jr., 1985, Geology of the Nanushuk Group related rocks, North Slope, Alaska: U.S. Geological Survey Bulletin 1614, 129. p.

Huffman, A.C., Jr., 1989, The Nanushuk Group, in C.G. Mull and K.E. Adams, eds., Dalton Highway, Yukon River to Prudhoe Bay, Alaska; Bedrock geology of the eastern Koyukuk basin, central Brooks Range, and eastcentral Arctic Slope, Guidebook--Alaska Division of Geological and Geophysical Surveys Report no. 7, v.2, p 303-309. Kelley, J.S., 1990, Generalized geologic map of the Chandler Lake

quadrangle, north-central Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2144-A, scale 1:250,000. Kelley, K.D., Barton, H.N., Sutley, S.J., and O'Leary, R.M., 1993a, Map showing distribution of selected elements in stream-sediment samples from the southern part of the Chandler Lake quadrangle, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-2144-C,

scale 1:250,000. Kelley, K.D., Sutley, S.J., and Frisken, J.G., 1993b, Maps showing the distribution of selected elements and mineralogy of nonmagnetic heavy-mineral-concentrate samples from the southern part of the Chandler Lake quadrangle: U.S. Geological Survey Miscellaneous

Field Studies MF-2144-B, scale 1:250,000. Levinson, A.A., 1974, Introduction to exploration geochemistry: Calgary Alberta, Applied Publishing Ltd., 612 p. Los Alamos National Laboratory, 1982, Uranium hydrogeochemical and stream-sediment reconnaissance of the Chandler Lake quadrangle,

Alaska: U.S. Department of Energy Report GJBX 49(82). Mull, C.G., 1982, The tectonic evolution and structural style of the Brooks Range, Alaska: An illustrated summary, in Powers, R. B., ed Geological studies of the Cordilleran thrust belt: Denver, Colorado,

Rocky Mountain Association of Geologists, v. 1, p. 1-45. Mull, C.G., Tailleur, I.L., Mayfield, C.F., Ellersieck, Inyo, and Curtis, S. 1982, New Upper Paleozoic and lower Mesozoic stratigraphic units central and western Brooks Range, Alaska: The American Association of Petroleum Geologists Bulletin, v. 66, no. 3, p. 348-362 Nilsen, T.H., Brosgé, W.P., Dutro, J.T., Jr., and Moore, T.E., 1981 Depositional model for the fluvial Upper Devonian Kanayu Conglomerate, Brooks Range, Alaska, in Albert, R. D., and Hudson

Travis, eds., The United States Geological Survey in Alaska--Accomplishments during 1979: U.S. Geological Survey Circular 823-B, p. B20-21. Nilsen, T.H., and Moore, T.E., 1984, Stratigraphic nomenclature for the Upper Devonian and Lower Mississippian(?) Kanayut Conglomerate,

Brooks Range, Alaska: U.S. Geological Survey Bulletin 1529-A, 64 Palache, Charles, Berman, Harry, and Frondel, Clifford, 1944, Danas system of mineralogy, seventh edition: New York, John Wiley and

Sons, Inc., 834 p. Patton, W.W., Jr., and Tailleur, I.L., 1964, Geology of the Upper Killik-Itkillik region, Alaska: U.S. Geological Survey Professional

Paper 303-G, p. 409-499. Rose, A.W., Hawkes, H.E., and Webb, J.S., 1979, Geochemistry in mineral exploration, London, Academic Press Inc., 657 p.

Siok, J.P., 1985, Geologic history of the Siksikpuk Formation on the Endicott Mountains and Picnic Creek allochthons, north-central Brooks Range, Alaska: Fairbanks, University of Alaska, M.S. thesis, Sutley, S.J., Duttweiler, K.A., and Hopkins, R.T., 1984, Analytical results

and sample locality map of stream-sediment and panned-concentrate

samples from the Chandler Lake 1° x 3° quadrangle, Alaska: U.S. Geological Survey Open-File Report 84-412, 30 p. Tailleur, I.L., and Brosgé, W.P., 1970, Tectonic history of northern Alaska, in Adkison, W.L., and Brosgé, M.M., eds., Geological seminar on the North Slope of Alaska, Palo Alto, Calif., 1970, Proceedings: Los Angeles, Calif., American Association of Petroleum Geologists Pacific Section, p. E1-E20.

Thompson, C. E., Nakagawa, H. M., and Van Sickle, G. H., 1968, Rapid analysis for gold in geologic materials, in Geological Survey Research 1968: U.S. Geological Survey Professional Paper 600-B, p.

Wahrhaftig, Clyde, 1965, Physiographic divisions of Alaska: U.S. Geological Survey Professional Paper 482, 52 p.

ARCTIC COASTAL PLAIN PROVINCE

BROOKS RANGE PROVINCE

Chandler Lake quadrangle, Alaska.

Chandler Lake Philip Smith

Figure 1. Index map of the central and eastern Brooks Range showing location of the

Karen D. Kelley and Stephen J. Sutley

0 100 km

Box 25286, Federal Center, Denver, CO 80225

quadrangle (Kelley, 1990). The southern part of the quadrangle is comprised of unmetamorphosed to weakly metamorphosed sedimentary rocks that are folded and thrust-faulted (Brosgé and others, 1979). The Upper Devonian Hunt Fork Shale, as described by Brosgé and others (1979), includes two

environment (Brosgé and others, 1979). Marine strata of the Hunt Fork Shale are overlain by the marine

geochemical data.